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In re Patent Application of

Tsutomu ASAKAWA et al

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For: METHOD OF PRODUCING AN ANTIREFLECTION-COATED SUBSTRATE

TRANSLATOR'S DECLARATION

Honorable Commissioner of Patents
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Sir:

I, Noriyasu Ikeda, of 1-15-7, Tamami, Asao-ku, Kawasaki-shi, Kanagawa, Japan, hereby certify that I am conversant with both the Japanese and the English languages, and that I have prepared the English translation attached hereto, which is a full, true and faithful translation of the patent application filed with the Patent Office of Japan under Application No. 2002-229473 on August 7, 2002 to the best of my knowledge and belief.

I further declare that all statements made in this declaration of my own knowledge are true and that all statements made on information and belief and believed to be true; and further, that these statements are made with the knowledge that willful, false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code and that such willful, false statements may jeopardize the validity of this application or any Patent issued thereon.

July 5, 2005
Date

Name: Noriyasu Ikeda

(Translation)

JAPAN PATENT OFFICE

This is to certify that the annexed is a true copy of the following application as filed with this Office.

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Applicant(s): HOYA CORPORATION

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[Inventor]

[Address] c/o HOYA CORPORATION, 7-5, Naka-Ochiai 2-chome, Shinjuku-ku, Tokyo

[Name] Tsutomu Asakawa

[Inventor]

[Address] c/o HOYA CORPORATION, 7-5, Naka-Ochiai 2-chome, Shinjuku-ku, Tokyo

[Name] Kenji Matsumoto

[Applicant]

[ID Number] 000113263]

[Address] 7-5, Naka-Ochiai 2-chome, Shinjuku-ku, Tokyo

[Name] HOYA CORPORATION

[Representative] Hiroshi Suzuki

[Attorney]

[ID Number] 100103676

[Patent Attorney]

[Name] Yasuo Fujimura

[Official Fee]

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[Name of Document] SPECIFICATION

[Title of Invention] DUST-PROOF SUBSTRATE FOR A LIQUID CRYSTAL PANEL AND METHOD OF PRODUCING THE SAME

[Claim for Patent]

[Claim 1] A dust-proof substrate for a liquid crystal panel, the dust-proof substrate comprising a transparent substrate and an antireflection film formed thereon, the antireflection film comprising a multilayer film having a medium refractive index layer made of a material containing silicon, tin, and oxygen, a high refractive index layer made of a material containing titanium and oxygen, and a low refractive index layer made of a material containing silicon and oxygen, these layers being successively formed on the transparent substrate in this order.

[Claim 2] The dust-proof substrate as claimed in claim 1, wherein the antireflection film has a reflectance of 0.5% or less and a transmittance of 95% or more in a visible range (430nm-650nm).

[Claim 3] The dust-proof substrate as claimed in claim 1 or 2, wherein the medium refractive index layer has a refractive index between 1.6 and 1.8, the high refractive index layer having a refractive index between 2.1 and 2.8, and the low refractive index layer having a refractive index between 1.4 and 1.46.

[Claim 4] A method of producing a dust-proof substrate for a liquid crystal panel, the dust-proof substrate comprising a transparent substrate and an antireflection film formed thereon, wherein:

the antireflection film is formed by sputtering or reactive sputtering in an inactive gas atmosphere or in a mixed gas atmosphere containing an inactive gas and an oxygen gas, a medium refractive index layer made of a material containing silicon, tin, and oxygen being deposited by the use of a material

containing silicon and tin as a target, a high refractive index layer made of a material containing titanium and oxygen being deposited by the use of a material containing titanium as a target, and a low refractive index layer made of a material containing silicon and oxygen being deposited by the use of a material containing silicon as a target, these layers being successively deposited on the transparent substrate in this order.

[Claim 5] The method as claimed in claim 4, wherein the antireflection film is formed by successively depositing these layers using an in-line sputtering apparatus.

[Detailed Description of the Invention]

[0001]

[Technical Field of the Invention]

This invention relates to a dust-proof substrate for use in a liquid crystal panel (in particular, a liquid crystal projector of a projection type).

[0002]

[Prior Art]

As illustrated in Fig. 4, a liquid crystal projector of a projection type is an apparatus in which a light beam emitted from a light source is condensed by a condensing optical system (not shown) and guided to a liquid crystal apparatus 100 and the light beam is optically modulated by a liquid crystal layer 50 and then projected to a screen via an optical system (not shown), such as a lens, so that a predetermined image is displayed. The light beam from the light source is condensed so that a focal point is positioned in the liquid crystal layer 50 of the liquid crystal apparatus 100. Therefore, if a flaw or a dust particle 201 is attached to an outer surface of an opposite substrate 20 and is located at a distance of about 1mm, which corresponds to the thickness of a substrate 21, from the liquid crystal layer 50 as a focal position, the flaw or the dust particle is present within a range of a focal distance and is put in a focused condition.

Similarly, if a flaw or a dust particle 202 is attached to an outer surface of a drive substrate 30 and is located at a distance of about 1mm, which corresponds to the thickness of a substrate 31, from the liquid crystal layer 50, the flaw or the dust particle is present within the range of the focal distance and is put in a focused condition. As a result, in case where the display is carried out by the use of the liquid crystal projector of a projection type comprising a liquid crystal cell with the flaw or the dust particle 201 or 202 attached to the outer surface, the flaw or the dust particle 201 or 202 appears in a projected image and the display quality is degraded. In order to avoid the above-mentioned problem, a pair of transparent substrates 41a and 41b, each of which has a thickness of about 1mm and is made of, for example, a glass, are disposed adjacent to the liquid crystal cell as dust-proof substrates 40a and 40b in a manner such that the liquid crystal cell is interposed therebetween. With this structure, it is possible to protect the outer surfaces of the substrates 20 and 30 of the liquid crystal cell from a flaw or a dust particle. Even if a flaw or a dust particle 211 or 212 is attached to the other surface of the dust-proof substrate 40a or 40b which is not adjacent to the liquid crystal cell, the flaw or the dust particle 211 or 212 is put in a defocused condition due to the thickness of the dust-proof substrate. Thus, the display quality is not degraded.

Generally, the dust-proof substrate mentioned above includes an antireflection film comprising an $Al_2O_3/ZrO_2/MgF_2$ multilayer film formed on one surface of a transparent substrate by vapor deposition. Proposal is also made of an antireflection film comprising a plurality of SiO_2 layers and ZrO_2 layers alternately laminated (JP-A 2000-282134).

[0003]

[Problem to be Solved by the Invention]

In case of the antireflection film comprising the $Al_2O_3/ZrO_2/MgF_2$ multilayer film formed by vapor deposition, foreign matters, splash, or pinholes

will be caused to occur by the vapor deposition. Presence of the foreign matters or the splash causes scattering of light while the presence of the pinholes causes reflection of light. As a result, it is impossible to achieve the optical characteristics required for the dust-proof substrate (the transmittance of 95% or more and the reflectance of 0.5% or less). Alternatively, the $Al_2O_3/ZrO_2/MgF_2$ multilayer film may be formed by reactive sputtering. However, it is extremely difficult to stably deposit MgF_2 as fluoride. Thus, stable optical characteristics can not be obtained and a heavy load is imposed upon production.

In case of the antireflection film comprising a plurality of SiO_2 layers and ZrO_2 layers alternately laminated, at least four layers are required and the film thickness must strictly be controlled for each layer. Thus, stable optical characteristics can not be obtained and a heavy load is imposed upon production.

[0004]

In view of the above-mentioned disadvantages, this invention has been made. It is an object of this invention to provide a dust-proof substrate for a liquid crystal panel, which has a high transmittance of 95% or more and a low reflectance of 0.5% or less and is therefore excellent in optical characteristics, and to provide a method of producing the same.

It is another object of this invention to provide a dust-proof substrate for a liquid crystal panel, which is excellent in film adhesion without causing film peeling even under a severe environment, and to provide a method of producing the same.

[0005]

[Means to Solve the Problem]

This invention has following structures.

(Structure 1) A dust-proof substrate for a liquid crystal panel, the dust-

proof substrate comprising a transparent substrate and an antireflection film formed thereon, the antireflection film comprising a multilayer film having a medium refractive index layer made of a material containing silicon, tin, and oxygen, a high refractive index layer made of a material containing titanium and oxygen, and a low refractive index layer made of a material containing silicon and oxygen, these layers being successively formed on the transparent substrate in this order.

(Structure 2) The dust-proof substrate for a liquid crystal panel according to structure 1, wherein the antireflection film has a reflectance of 0.5% or less and a transmittance of 95% or more in a visible range (430nm-650nm).

(Structure 3) The dust-proof substrate for a liquid crystal panel according to structure 1 or 2, wherein the medium refractive index layer has a refractive index between 1.6 and 1.8, the high refractive index layer having a refractive index between 2.1 and 2.8, and the low refractive index layer having a refractive index between 1.4 and 1.46.

(Structure 4) A method of producing a dust-proof substrate for a liquid crystal panel, the dust-proof substrate comprising a transparent substrate and an antireflection film formed thereon, wherein:

the antireflection film is formed by sputtering or reactive sputtering in an inactive gas atmosphere or in a mixed gas atmosphere containing an inactive gas and an oxygen gas, a medium refractive index layer made of a material containing silicon, tin, and oxygen being deposited by the use of a material containing silicon and tin as a target, a high refractive index layer made of a material containing titanium and oxygen being deposited by the use of a material containing titanium as a target, and a low refractive index layer made of a material containing silicon and oxygen being deposited by the use of a material containing silicon as a target, these layers being successively deposited on the transparent substrate in this order.

(Structure 5) The method of producing a dust-proof substrate for a liquid crystal panel according to structure 4, wherein the antireflection film is formed by successively depositing these layers using an in-line sputtering apparatus.

[0006]

[Mode of Embodying the Invention]

A dust-proof substrate for a liquid crystal panel according to this invention comprises a transparent substrate and an antireflection film formed thereon and is characterized in that the antireflection film comprises a multilayer film having three layers, i.e., a medium refractive index layer made of a material containing silicon, tin, and oxygen, a high refractive index layer made of a material containing titanium and oxygen, and a low refractive index layer made of a material containing silicon and oxygen, these layers being successively formed on the transparent substrate in this order.

With the above-mentioned film structure, it is possible to achieve a high transmittance of 95% or more and a low reflectance of 0.5% or less in a visible range (430nm-650nm). The antireflection film in this invention preferably has a reflectance of 0.5% or less and a transmittance of 95% or more in a visible range (430nm-650nm).

In order to obtain the above-mentioned optical characteristics, the refractive index of each of the medium refractive index layer, the high refractive index layer, and the low refractive index layer is preferably 1.6-1.8 for the medium refractive index layer, 2.1-2.8 (preferably 2.2-2.6) for the high refractive index layer, and 1.4-1.46 for the low refractive index layer.

An oxide film containing silicon, tin, and oxygen has a high transmittance and an excellent chemical resistance (corrosion resistance, alkali resistance). In addition, in case where a film made of a material containing titanium and oxygen, for example, a titanium oxide film is formed on the oxide film, oxygen

loss of the titanium oxide film (TiO_2) can be prevented. It is therefore possible to obtain the titanium oxide film having a high transmittance and transparent in a visible range. The oxide film containing silicon, tin, and oxygen may be formed by sputtering in an inactive gas atmosphere or in a mixed gas atmosphere containing an inactive gas and an oxygen gas by the use of a target containing silicon, tin, and oxygen or by reactive sputtering in a mixed gas atmosphere containing an inactive gas and an oxygen gas by the use of a target containing silicon and tin. Preferably, the oxide film containing silicon, tin, and oxygen is formed by reactive sputtering in a mixed gas atmosphere containing an inactive gas and an oxygen gas by the use of a target containing silicon and tin.

The film made of a material containing titanium and oxygen (titanium oxide film) is formed by sputtering or reactive sputtering in an inactive gas atmosphere or in a mixed gas atmosphere containing an inactive gas and an oxygen gas by the use of a material containing titanium (for example, TiO_2, TiO_{2-x}, or Ti) as a target. Preferably, the film made of a material containing titanium and oxygen is formed by sputtering in an inactive gas atmosphere by the use of TiO_2 or TiO_{2-x} as a target. This is because shortage of oxygen contained in the titanium oxide film is prevented.

The film made of a material containing silicon and oxygen (silicon oxide film) is formed by sputtering or reactive sputtering in an inactive gas atmosphere or in a mixed gas atmosphere containing an inactive gas and an oxygen gas by the use of a material containing silicon (for example, containing at least one of Si, SiC, SiO_2) as a target. Preferably, the film made of a material containing silicon and oxygen is formed by reactive sputtering in a mixed gas atmosphere containing an inactive gas and an oxygen gas by the use of the material containing silicon (containing at least one selected from SiO and SiO_2) as a target. This is because shortage of oxygen contained in the silicon oxide film is prevented.

As a sputtering method, direct current (DC) sputtering or radio frequency (RF) sputtering is available. In order to obtain a film uniform and excellent in quality, the direct current (DC) sputtering is preferable. As a target to be sputtered by the direct current (DC) sputtering, a (Si-Sn) target made of silicon and tin is preferably used in order to deposit the oxide film containing silicon, tin, and oxygen. In order to deposit the titanium oxide film, a target of TiO_2 or TiO_{2-x} is preferably used. In order to deposit the silicon oxide film, a SiC (silicon carbide) target is preferably used.

As a sputtering method, a method using an opposed target static deposition sputtering apparatus or a method using an in-line sputtering apparatus is available. The method using an opposed target static deposition apparatus is preferable in that an unnecessary oxide film is not formed between respective layers of the antireflection film, that the antireflection-coated substrate excellent in reliability without causing film peeling is obtained because a film boundary is not substantially formed at each layer, that the antireflection film is suppressed in occurrence of defects, such as foreign matters, splash, and pinholes, and that the productivity is excellent.

The oxygen gas is not only a pure oxygen gas but also may contain an additional component as far as the refractive index in each film falls within the above-mentioned range. As the additional component, nitrogen or carbon may be used. In this case, an acidic gas, such as an NO gas (nitrogen oxide), N_2O (nitrous oxide), NO_2 (nitrogen dioxide), or CO_2 (carbon dioxide) may be used.

[0007]

In this invention, the transparent substrate is made of a material having a high transmittance in a frequency range over which it is used. Since the liquid crystal panel is used in a visible range, a glass is generally used. For example, a quartz glass, glass ceramics, an alkali-free glass, and so on may be used. Generally, a quartz glass is used as an opposite substrate for use in the liquid

crystal panel. In this case, the transparent substrate is preferably made of a quartz glass which is a material same as that of the opposite substrate, or glass ceramics having a small coefficient of thermal expansion. As glass ceramics having an average coefficient of thermal expansion between -5 x 10^{-7}/°C and +5 x 10^{-7}/°C, glass ceramics having a crystal phase containing β-quartz solid solution is available. For example, use may be made of the glass ceramics which is obtained by preparing a glass ceramics raw material glass having a glass composition of 55-70 mol% SiO_2, 13-23 mol% Al_2O_3, 11-21 mol% alkali metal oxides (where the content of Li_2O is 10-20 mol% and the total content of Na_2O+K_2O is 0.1-3 mol%), 0.1-4 mol% TiO_2, 0.1-2 mol% ZrO_2, the total content of the above-mentioned components being 95 mol% or more, 0-0.2 (0.2 exclusive) mol% BaO, 0-0.1 (0.1 exclusive) mol% P_2O_5, 0-0.3 (0.3 exclusive) mol% B_2O_3, and 0-0.1 (0.1 exclusive) mol% SnO_2, and heat-treating the raw material glass to precipitate a crystal phase containing β-quartz solid solution.

[0008]

[Examples]

[Example 1]

Fig. 1 is a view for describing a dust-proof substrate for a liquid crystal panel according to this invention. Fig. 2 is a view for describing an in-line sputtering apparatus for producing the dust-proof substrate for a liquid crystal panel according to this invention.

Now, referring to Figs. 1 and 2, description will be made of the dust-proof substrate for a liquid crystal panel according to this invention and a method of producing the same.

In this example, as illustrated in Fig. 1, the dust-proof substrate for a liquid crystal panel comprises a transparent substrate 1 of a quartz glass on which a medium refractive index layer 2 ($Si_xSn_yO_z$) made of a material containing

silicon, tin, and oxygen, a high refractive index layer 3 (TiO_2) of titanium oxide, and a low refractive index layer 4 (SiO_2) of silicon oxide are successively laminated. The refractive index and the thickness of each of the medium refractive index layer, the high refractive index layer, and the low refractive index layer are as follows: The medium refractive index layer has the refractive index nm = 1.7 and the thickness dm = 77 nm. The high refractive index layer has the refractive index nh = 2.4 and the thickness dh = 110 nm. The low refractive index layer has the refractive index nl = 1.46 and the thickness dl = 90 nm.

Next referring to Fig. 2, the method of producing the dust-proof substrate for a liquid crystal panel in this example will be described. A quartz glass substrate 1 preliminarily subjected to grinding and polishing and having the size of 200 mm x 200 mm and the thickness of 1.1 mm was mounted on a substrate holder (pallet) 5. The pallet 5 was introduced into a loading chamber 7 of an in-line DC magnetron sputtering apparatus 6 illustrated in Fig. 2. Thereafter, the loading chamber was evacuated from an atmospheric condition to a vacuum degree equivalent to that of a sputtering chamber (vacuum chamber) 8. Then, a partitioning plate 9 was opened to introduce the pallet into the vacuum chamber. The pallet was moved at a predetermined transfer speed to pass a medium refractive index layer target 10, a high refractive index layer target 11, and a low refractive index layer target 12 successively disposed in a transfer direction of the pallet and put in a discharge state. A material of each target is as follows. The medium refractive index layer target 10: Si-Sn (Si: 50 at%, Sn: 50 at%). The high refractive index layer target 11: TiO_{2-x}. The low refractive index layer target 12: SiC. These targets were disposed in the above-mentioned order in the transfer direction of the pallet. In accordance with the order of the targets disposed as mentioned above, the medium refractive index layer ($Si_xSn_yO_z$, having the refractive index of 1.7 and the thickness of 77 nm), the high refractive index layer (TiO_2, having the refractive index of 2.4 and the

thickness of 110 nm), and the low refractive index layer (SiO_2, having the refractive index of 1.46 and the thickness of 90 nm) were successively laminated in this order. Next, a partitioning plate 14 adjacent to an unloading chamber 13 preliminarily evacuated to a vacuum degree substantially equivalent to that of the vacuum chamber was opened to transfer the pallet into the unloading chamber 13. Deposition of these layers was carried out in the vacuum chamber kept in a mixed gas atmosphere containing an argon gas and an oxygen gas.

In the above-mentioned manner, an antireflection-coated quartz glass substrate was obtained which comprised the quartz glass substrate 1 with the medium refractive index layer 2, the high refractive index layer 3, and the low refractive index layer 4 formed thereon.

Next, the above-mentioned substrate was cut into the size of 25 mm x 18 mm to obtain the dust-proof substrate for a liquid crystal panel in this example.

For the dust-proof substrate for a liquid crystal panel thus obtained, measurement was made of the transmittance and the reflectance in a visible range (430-650 nm). As a result, the transmittance was 96% or more and the reflectance was 0.4% or less. Thus, the optical characteristics were excellent. Foreign matters or pinholes having a size of 10 μm or more were not found in the antireflection film.

In order to evaluate the film adhesion, the dust-proof substrate for a liquid crystal panel thus obtained was subjected to a pressure cooker test (the substrate was left in an environment of 1.2 atm and 120°C for 1000 hours). As a result, no film peeling was observed after the pressure cooker test. This is presumably because the antireflection film was formed without an unnecessary oxide film formed between the respective layers of the antireflection film.

[0009]

[Example 2]

Three sputtering apparatuses of an opposed target static deposition type were provided. A medium refractive index layer target (Si-Sn (Si: 50 at% and Sn: 50 at%)), a high refractive index layer target (TiO_{2-x}), and a low refractive index layer target (SiO_2) were placed in these sputtering apparatuses, respectively. On a quartz glass substrate, a medium refractive index layer ($Si_xSn_yO_z$, having the refractive index of 1.7 and the thickness of 77 nm), a high refractive index layer (TiO_2, having the refractive index of 2.4 and the thickness of 110 nm), and a low refractive index layer (SiO_2, having the refractive index of 1.46 and the thickness of 90 nm) were successively deposited in this order. Deposition was carried out in a vacuum chamber kept in a mixed gas atmosphere containing an argon gas and an oxygen gas. The medium refractive index layer and the high refractive index layer were sputtered by direct current (DC) sputtering while the low refractive index layer was sputtered by radio frequency (RF) sputtering. The quartz glass substrate was transferred in atmospheric air when the quartz glass substrate was moved among these sputtering apparatuses.

For the dust-proof substrate for a liquid crystal panel thus obtained, measurement was made of the transmittance and the reflectance in a visible range (430-650 nm). As a result, the transmittance was 95% or more and the reflectance was 0.5% or less. Thus, the optical characteristics were excellent. Foreign matters or pinholes having a size of 10 μm or more were not found in the antireflection film.

The dust-proof substrate for a liquid crystal panel thus obtained was subjected to a pressure cooker test (the substrate was left in an environment of 1.2 atm and 120°C for 1000 hours). As a result, film peeling was observed in some samples after the pressure cooker test. This is presumably because the substrate was temporarily taken out into atmospheric air during deposition of the

respective layers of the antireflection film and, as a result, an unnecessary oxide film was formed between the respective layers.

From the above-mentioned results in the examples 1 and 2, it is understood that the antireflection film is preferably formed by successive deposition using an in-line sputtering apparatus in order to improve the film adhesion of the antireflection film.

[0010]

[Comparative Example 1]

A dust-proof substrate for a liquid crystal panel was produced in the manner similar to Example 1 except that the antireflection film is formed by successively depositing an aluminum oxide film (Al_2O_3), a zirconium oxide film (ZrO_2), and a magnesium fluoride film (MgF_2) on a quartz glass substrate in this order by vacuum deposition. The aluminum oxide film, the zirconium oxide film, and the magnesium oxide film had a film thickness of 83 nm, 132 nm, and 98 nm, respectively.

The antireflection film formed in the dust-proof substrate for a liquid crystal panel thus obtained was observed. As a result, a number of foreign matters and pinholes having a size of 10 μm or more and inherent to the vapor deposition were confirmed in the antireflection film. Measurement was made of the transmittance and the reflectance in a visible range (430-650 nm). As a result, in some samples, the transmittance was about 94% and the reflectance was about 0.6%. Thus, some samples did not satisfy the optical characteristics for the dust-proof substrate for a liquid crystal panel.

The dust-proof substrate for a liquid crystal panel thus obtained was subjected to a pressure cooker test (the substrate was left in an environment of 1.2 atm and 120°C for 1000 hours). As a result, film peeling was observed in some samples after the pressure cooker test.

[0011]

[Example of Production of Liquid Crystal Panel for Projection-type Liquid Crystal Projector]

Hereinafter, description will be made of an example of production of a liquid crystal panel for a projection-type liquid crystal projector by combining the dust-proof substrate prepared in the above-mentioned example and an opposite substrate for a liquid crystal panel separately prepared.

Generally, a liquid crystal panel for use in a liquid crystal display comprises a liquid crystal layer, and a drive substrate and an opposite substrate which are arranged opposite to each other with the liquid crystal layer interposed therebetween and which serve to hold and drive the liquid crystal layer. The drive substrate comprises a base substrate, pixel electrodes formed on the base substrate, and a switching device connected to the pixel electrodes. On the other hand, the opposite substrate comprises a light transmitting substrate and an opposite electrode formed on the light transmitting substrate at a position opposite to the pixel electrodes. The liquid crystal layer is held between the drive substrate and the opposite substrate via orientation films and is driven by an electric voltage applied between the pixel electrodes and the opposite electrode.

[0012]

Depending upon the orientation of the liquid crystal layer controlled by the pixel electrodes and the opposite electrode, a light beam incident on the side of the opposite substrate is controlled in transmittance for each pixel to form a predetermined image. Furthermore, in the above-mentioned liquid crystal panel, a light transmitting substrate having a predetermined thickness as a dust-proof substrate may be bonded to an outer surface of at least one of the drive substrate and the opposite substrate for the purpose of heat release and in order to prevent deterioration in picture quality caused by a dust or the like adhered to the liquid crystal panel.

In this example of production of the liquid crystal panel, the dust-proof substrate prepared in the above-mentioned example was bonded to the outer surface of each of the drive substrate and the opposite substrate.

Fig. 1 is a schematic view showing one example of a structure of the liquid crystal panel provided with the dust-proof substrate. In this example, dust-proof substrates 40a and 40b are bonded to outer surfaces of both of an opposite substrate 20 and a drive substrate 30 of a liquid crystal panel 100.

[0013]

At first, the opposite substrate 20 will be described.

The opposite substrate 20 comprises a light transmitting substrate 21 and an opposite electrode 23 formed thereon. If necessary, a light shielding layer 22 is formed in a matrix fashion at positions opposite to switching devices 33 of the drive substrate 30 in order to prevent an incident light beam from being incident to the switching devices 33 formed on the drive substrate.

The light shielding layer 22 is generally made of a material capable of shielding the incident light beam. Preferably, the light shielding layer has a high reflectance film on a light incident side in order to prevent malfunction of the liquid crystal panel due to heat absorbed by the light shielding layer. Furthermore, the light shielding layer preferably has a low reflectance film on a drive substrate side in order to prevent stray light in the liquid crystal layer. More preferably, the light shielding layer 22 comprises a multilayer film composed of a high reflectance film and a low reflectance film formed on the light incident side and on the drive substrate side, respectively. The light shielding layer may be formed on the light transmitting substrate 21 by the photolithography or the like known in the art.

The opposite electrode 23 on the light transmitting substrate 21 controls the orientation of the liquid crystal layer 50, in cooperation with pixel electrodes 32 on the drive substrate 30. The opposite electrode 23 is made of a material

transparent to the incident light beam and having conductivity, for example, a transparent conductive film. As a material transparent to a visible light beam and having conductivity, an ITO film is available. The transparent conductive film may be formed by a known technique.

In order to effectively introduce the incident light beam into a pixel region, the opposite substrate 20 may be provided with a substrate having a microlens array formed on a light incident surface thereof. In this event, the substrate having the microlens array is bonded to the dust-proof substrate by the use of an adhesive (thermosetting resin or the like).

In necessary, the opposite substrate may be provided with a color filter. In this event, color display can be carried out.

[0014]

Next, the dust-proof substrates 40a and 40b will be described.

The dust-proof substrates 40a and 40b are bonded to the outer surfaces of the opposite substrate 20 and the drive substrate 30, respectively, for the purpose of heat release and in order to prevent deterioration in picture quality due to a dust adhered to the opposite substrate 20 or the drive substrate 30. The dust-proof substrates 40a and 40b comprise transparent substrates 41a and 41b on which antireflection films 42a and 42b produced in the above-mentioned example 1 and formed by successively laminating the medium refractive index layer ($Si_xSn_yO_z$), the high refractive index layer (TiO_2) made of titanium oxide, and the low refractive index layer (SiO_2) made of silicon oxide are provided, respectively.

Instead of the dust-proof substrates 40a and 40b, a single dust-proof substrate may be formed on the outer surface of one of the opposite substrate 20 and the drive substrate 30.

In order to prevent the incidence of light to a wiring for driving the switching devices of the drive substrate 30, a light shielding film having a

predetermined width may be formed on an outer periphery of the dust-proof substrate.

[0015]

The dust-proof substrate for a liquid crystal panel in this invention may be used for a reflective liquid crystal panel, such as a reflective projector.

[0016]

In the example 1 described above, the quartz substrate was used as the transparent substrate for the dust-proof substrate. However, as the transparent substrates 41a and 41b illustrated in Fig. 3, glass ceramics excellent in various characteristics may be used instead of the quartz substrate.

As the glass ceramics, glass ceramics having a crystal phase containing β-quartz solid solution is available. For example, use may be made of the glass ceramics which is obtained by preparing a glass ceramics raw material glass having a glass composition of 55-70 mol% SiO_2, 13-23 mol% Al_2O_3, 11-21 mol% alkali metal oxides (where the content of Li_2O is 10-20 mol% and the total content of Na_2O+K_2O is 0.1-3 mol%), 0.1-4 mol% TiO_2, 0.1-2 mol% ZrO_2, the total content of the above-mentioned components being 95 mol% or more, 0-0.2 (0.2 exclusive) mol% BaO, 0-0.1 (0.1 exclusive) mol% P_2O_5, 0-0.3 (0.3 exclusive) mol% B_2O_3, and 0-0.1 (0.1 exclusive) mol% SnO_2, and heat-treating the raw material glass to precipitate a crystal phase containing β-quartz solid solution.

The above-mentioned glass ceramics has a high spectral transmittance (transparency) in a visible light range, a low thermal expansion characteristic, a small specific gravity and a light weight (the specific gravity being not smaller than 2.2 and smaller than 2.5). Therefore, the glass ceramics can be used instead of the quartz glass which is expensive. As regards the spectral transmittance (transparency), the spectral transmittance in a range of 400-750 nm is 70% or more per the thickness of 5 mm and/or the spectral transmittance

in a range of 400-750 nm is 85% or more per the thickness of 1.1 mm. Since the coefficient of thermal expansion is small (specifically, the average coefficient of thermal expansion is between -5 x 10^{-7}/°C and +5 x 10^{-7}/°C in a temperature range of 30-300°C), heat shock resistance is superior. The light weight is advantageous for reduction in weight of the liquid crystal panel. In addition, the productivity of the glass ceramics itself is good so that the low cost is achieved. Thus, the glass ceramics is advantageously used as a material of the dust-proof substrate for a liquid crystal projector. As compared with other glass ceramics substrates, the above-mentioned glass ceramics substrate has an excellent transmittance at around 365 nm which is useful for ultraviolet setting and, therefore, can be bonded by the use of an ultraviolet setting resin.

A raw material glass for the above-mentioned glass ceramics has a relatively low melting temperature. Therefore, by the use of a melting furnace for a typical optical glass, the raw material glass extremely excellent in homogeneity can be obtained. In addition to the composition hardly colored, impurities causing coloration are hardly released from a container or a refractory to be mixed during melting of the glass. Thus, the glass ceramics having a high spectral transmittance in a visible light range, a low thermal expansion characteristic, and a low specific gravity can be produced by crystallization in a relatively short time.

The above-mentioned glass ceramics substrate may advantageously be used as the opposite substrate 20 in the liquid crystal panel described in conjunction with Fig. 3.

[0017]

[Effect of the Invention]

According to this invention, it is possible to provide a dust-proof substrate for a liquid crystal panel, which has a high transmittance of 95% or more and a low reflectance of 0.5% or less and is therefore excellent in optical

characteristics, and to provide a method of producing the same.

It is also possible to provide a dust-proof substrate for a liquid crystal panel, which is excellent in film adhesion without causing film peeling even under a severe environment, and to provide a method of producing the same.

[Brief Description of the Drawing]

[Fig. 1]

A schematic view for describing a dust-proof substrate for a liquid crystal panel according to this invention;

[Fig. 2]

A schematic view for describing an in-line sputtering apparatus for producing the dust-proof substrate for a liquid crystal panel according to this invention.

[Fig. 3]

A schematic view showing one example of a structure of a liquid crystal panel with the dust-proof substrate.

[Fig. 4]

A schematic view for describing an effect of the dust-proof substrate.

[Description of Reference Numerals]

1 transparent substrate

2 medium refractive index layer

3 high refractive index layer

4 low refractive index layer

41a dust-proof substrate

41b dust-proof substrate

42a antireflection film

42b antireflection film

100 liquid crystal panel

[Name of Document] ABSTRACT

[Abstract]

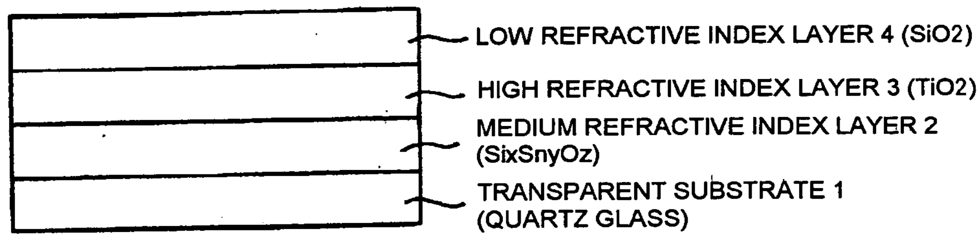
[Object] To provide a dust-proof substrate for a liquid crystal panel, which has a high transmittance of 95% or more and a low reflectance of 0.5% or less and is therefore excellent in optical characteristics, and to provide a method of producing the same.

[Solution] A dust-proof substrate for a liquid crystal panel which includes a transparent substrate 1 and an antireflection film formed thereon and which is characterized in that the antireflection film is a multilayer film having a medium refractive index layer 2 made of a material containing silicon, tin, and oxygen, a high refractive index layer 3 made of titanium oxide, and a low refractive index layer made of silicon oxide, these layers being successively formed on the transparent substrate 1 in this order.

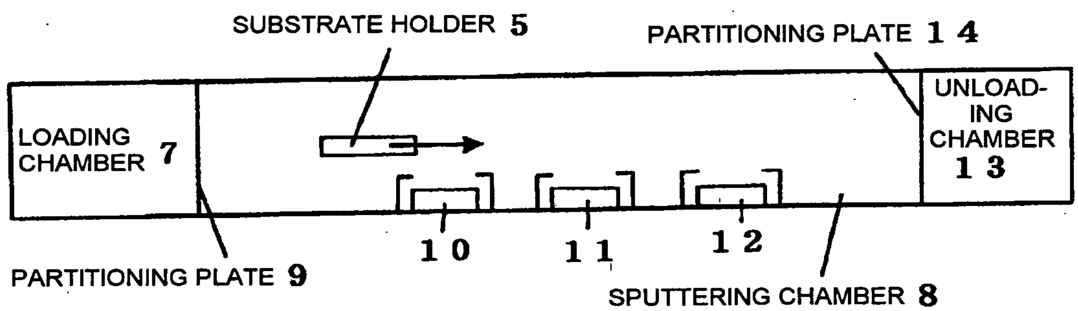
[Selected Figure] Fig. 1

[Name of Document] DRAWING

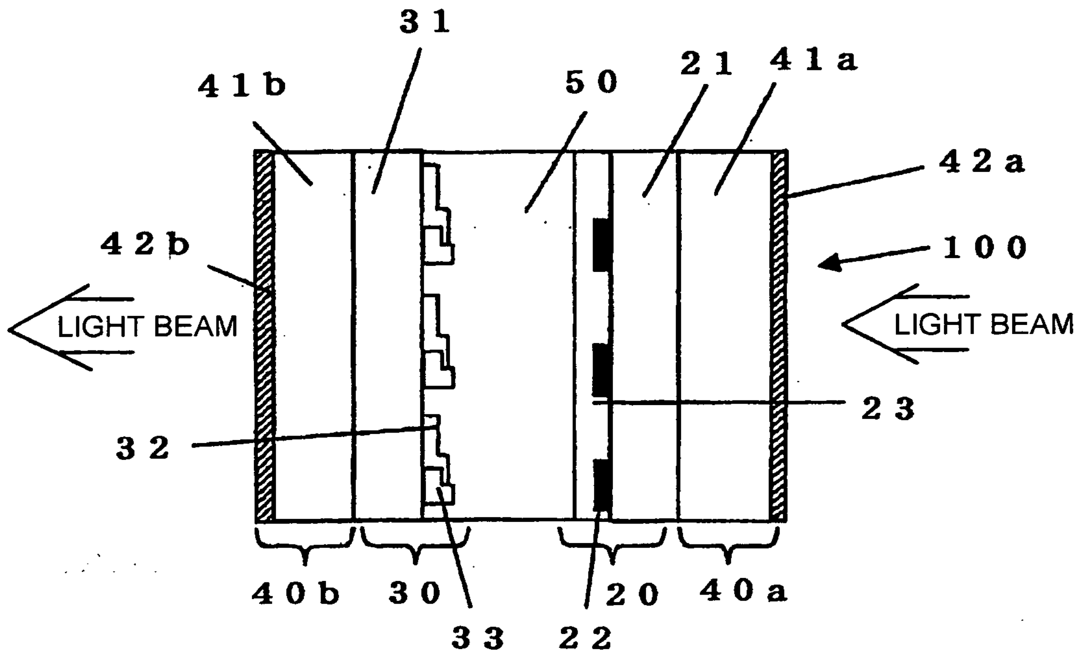
[Fig. 1]



[Fig. 2]

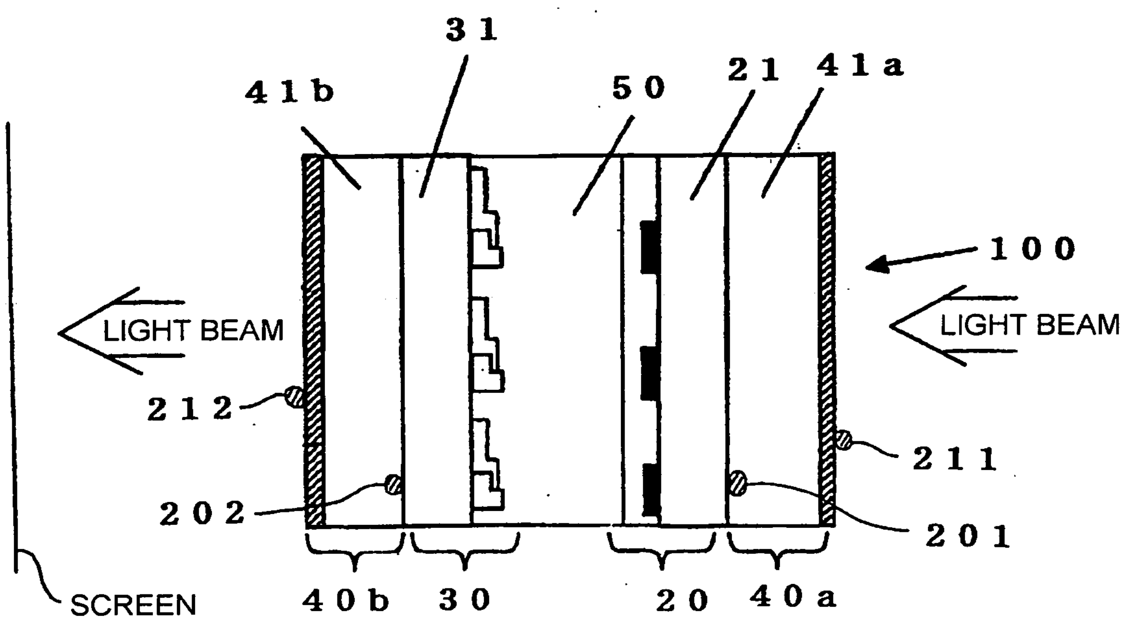


[Fig. 3]



31
41b
50
21
41a
42a
42b
100
LIGHT BEAM
LIGHT BEAM
23
32
40b
30
20
40a
33
22

[Fig. 4]



31
41b
50
21
41a
100
LIGHT BEAM
LIGHT BEAM
212
211
202
201
SCREEN
40b
30
20
40a